

PCT

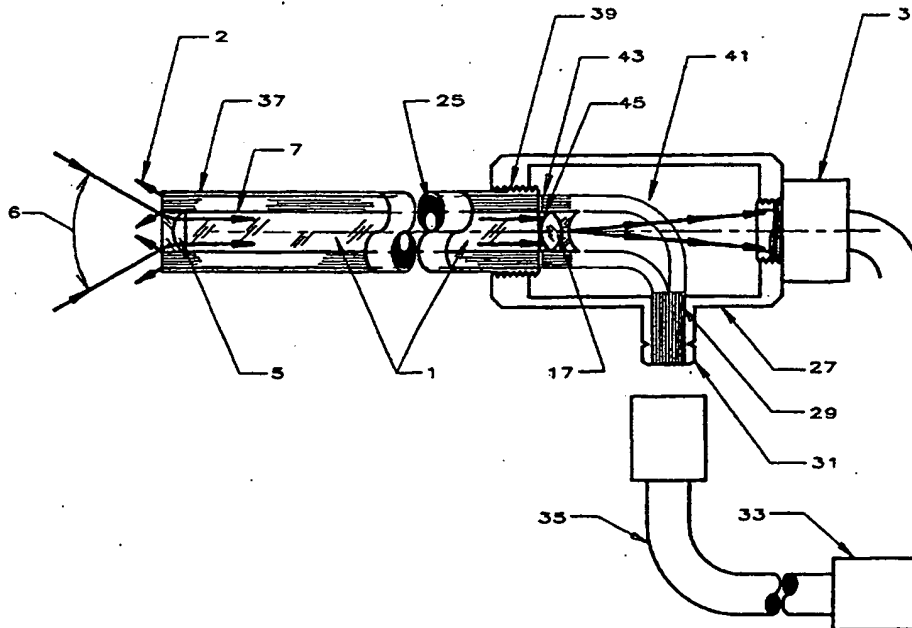
WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>5</sup> : <b>A61B 1/00, 1/04</b>		A1	(11) International Publication Number: <b>WO 94/14367</b>
			(43) International Publication Date: <b>7 July 1994 (07.07.94)</b>
(21) International Application Number: <b>PCT/US93/12489</b>		(74) Agents: <b>ZELANO, Anthony, J. et al.; Millen, White, Zelano &amp; Branigan, Arlington Courthouse Plaza 1, Suite 1400, 2200 Clarendon Boulevard, Arlington, VA 22201 (US).</b>	
(22) International Filing Date: <b>20 December 1993 (20.12.93)</b>			
(30) Priority Data: <b>07/992,660 18 December 1992 (18.12.92) US</b>		(81) Designated States: <b>AU, CA, JP, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).</b>	
(60) Parent Application or Grant (63) Related by Continuation <b>US 07/992,669 (CIP) Filed on 18 December 1992 (18.12.92)</b>		<b>Published</b> <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>	
(71) Applicant (for all designated States except US): <b>SCHOTT FIBER OPTICS INC. [US/US]; 122 Charlton Street, Southbridge, MA 01550 (US).</b>			
(72) Inventors; and (75) Inventors/Applicants (for US only): <b>SIEGMUND, Walter, P. [US/US]; Cassidy Road, Pomfret Center, CO 06259 (US). REMJAN, Paul, W. [US/US]; Blodgett Road, Holland, ME 01521 (US). SMITH, John, M. [US/US]; 20 Tillyer Avenue, Southbridge, MA 01550 (US).</b>			

(54) Title: **RIGID ENDOSCOPE PROVIDED WITH IMAGE TRANSMITTING ROD**



BEST AVAILABLE COPY

AL

**(57) Abstract**

A rigid endoscope comprises a high refractive index (HRI) tunnel rod (1), preferably made of glass, for transfer of image light from a distal end to a proximal end of the device, such HRI tunnel rod is provided with a blackened surface (7) so that a minimum of light is scattered and reflected within the rod. The HRI tunnel rod shortens the apparent distance from the proximal to the distal end by virtue of its refractive index being greater than that of air, and also provides a light tunnel (25) which can carry the image over a relatively long distance by virtue of its modified inside walls. Relatively simple lenses (5, 17) are incorporated at the ends of the rod for image formation so as to cover a wide object field and to relay the image to a video camera (3). Stereo measuring embodiments of the endoscope provides dual optical paths for yielding two images containing parallax data.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgyzstan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo	KR	Republic of Korea	SE	Sweden
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LI	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LJ	Luxembourg	TD	Chad
CS	Czechoslovakia	LV	Latvia	TG	Togo
CZ	Czech Republic	MC	Monaco	TJ	Tajikistan
DE	Germany	MD	Republic of Moldova	TT	Trinidad and Tobago
DK	Denmark	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	US	United States of America
FI	Finland	MN	Mongolia	UZ	Uzbekistan
FR	France			VN	Viet Nam
GA	Gabon				

Rigid endoscope provided with image transmitting rod

5

#### BACKGROUND OF THE INVENTION

The invention relates to rigid endoscopes for viewing into generally inaccessible areas, such as various body cavities or industrial components. Endoscopes for remotely viewing into body cavities or industrial components are well-known. Such endoscopes can be divided into two categories, rigid and flexible. Most flexible endoscopes utilize fiber optic image transfer bundles to carry the image from the distal tip to the proximal eyepiece. Other flexible endoscopes employ a small CCD chip at the distal tip and use fiber optics only for illumination and not for direct transfer of the image.

Most modern rigid endoscopes are of the "rod-lens" type, which utilize a train of rod-like lenses to relay the image of an object from a distal end to a proximal eyepiece or other viewing means, such as a CCD camera. Such a device is taught in U.S.P. No. 4,168,882 to Hopkins, whose entire disclosure is incorporated herein by reference. In that device, the image of an object area is formed by a first distal lens. A second lens reimages the first image to a third lens, which reimages the second image to a fourth lens, and so on, until the image is relayed to the viewing means.

Rigid endoscopes employing a train of lenses for image

transfer require many lenses in order to transfer the image through a slender tube while retaining good resolving capabilities and a wide field of view. It is necessary that endoscope probe lengths reach as high as 30-40 centimeters, and such lengths require as many as 20-30 lenses in order to transmit a clear, bright image. Each lens requires grinding, polishing, and coating to obtain high optical quality, and must be aligned and mounted in a rigid encasement with great precision. As a result, the cost of producing such rigid endoscopes is very high. Further, such expensive rod-lens construction precludes the feasibility of removal and disposal of the whole shaft after a single use, which would be a preferred option, especially for cleanliness in medical applications. Removable, disposable sheaths which cover the length of the shaft have been proposed. However, such sheaths do not provide adequate protection against bacterial contamination, are cumbersome to work with, and are susceptible to breakage.

Stereo versions of rod-lens type endoscopes are also known in the prior art. For example, U.S. Patent No. 5,122,650 to McKinley, the entire disclosure of which is incorporated herein by reference, teaches such an endoscope. However, substantial modifications to the basic rod-lens design must be made to obtain independent optical paths in the shaft portion in order to yield two images containing parallax data, such images being essential for production of a stereo image. These modifications require

much duplication of optical elements, especially in the shaft portion, which results in an endoscope which is costly and is even less suitable for disposability of the shaft.

5

#### SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved rigid endoscope. This invention provides such an endoscope which can be constructed at a lower cost relative to prior art devices with comparable lengths and resolving capabilities. Moreover, the rigid endoscope of the invention comprises a shaft which is constructed in such a manner, and from such materials, as to allow it to be removed and disposed of at a low cost.

15 The present invention provides a rigid endoscope utilizing a solid transparent high refractive index (HRI) tunnel rod, preferably made of glass, in place of the conventional train of lenses discussed above, for conducting image light from a distal end to a proximal end of the device, the outer surface of such rod being modified so that a minimum of light is scattered and/or reflected within the rod, thus minimizing veiling glare and contrast reduction of the image which is formed by the proximal optics near the HRI tunnel rod's proximal end.

25 Relatively simple lenses are incorporated at the ends of the HRI tunnel rod for image formation so as to cover a wide object field and to relay the image to a receiving device, such as a video camera.

In one aspect, this invention provides a rigid endoscope device useful for remotely examining a cavity, comprising distal optics for forming an image of an object area to be examined, an HRI tunnel rod of transparent material having an index of refraction greater than 1 for conducting image light from a distal end to a proximal end of said endoscope, the HRI tunnel rod having an outer surface which is blackened effectively to inhibit internal scattering of light, proximal optics located at a proximal end of the HRI tunnel rod, the proximal optics serving to relay an image of an object area to be examined, and a means for receiving and displaying the image relayed from the proximal optics.

The HRI tunnel rod serves two major purposes: 1) it shortens the apparent distance from the proximal to the distal end by virtue of its refractive index being greater than that of air, and 2) it provides a light tunnel which can transmit image light over a relatively long distance without veiling energy from wall scatter by virtue of its modified inside walls. A preferred method of modification is by exposing the HRI tunnel rod to a reducing atmosphere, thereby reducing metal oxides to metal around the outer surface of the HRI tunnel rod to create a thoroughly blackened outer surface whose inner-diameter surface is greatly non-reflective, even at grazing incidences. A preferred reducing method is hydrogen firing, wherein the HRI tunnel rod is exposed to a heated atmosphere of hydrogen. Such methods are taught in detail in U.S. Patent

No. 4,760,307 to Howorth, 5,074,899 to Howorth, and U.S. Patent No. 5,078,773 to Thomas.

In a second aspect, the invention provides an improved stereo measuring endoscope which resolves bright, clear images, contains fewer optical components, is less costly to manufacture, and which provides a shaft that may be disposed of at a low cost.

In a third aspect, the invention provides a method of producing a shaft for a rigid endoscope which is capable of accurately transmitting image light of high resolution from a distal end of the endoscope to a proximal end thereof, comprising modifying a rod of high refractive index transparent material by blackening the outer surface of the HRI tunnel rod, thereby creating an inner surface which minimizes the amount of light scattered and reflected within the HRI tunnel rod to an extent that veiling glare and contrast reduction of an image transmitted by the HRI tunnel rod are reduced, and surrounding the HRI tunnel rod with a ring of light-conducting members, the light-conducting members being oriented so as to run generally parallel to the HRI tunnel rod.

The foregoing and other objects, features, and advantages of the invention will be apparent from the following more particular description of the preferred embodiments as illustrated in the accompanying drawings in which reference characters refer to the same parts throughout the various views. The drawings are not necessarily to scale, emphasis instead being placed upon

illustrating the principles of the invention.

Fig. 1 shows the basic elements of the endoscope according to a preferred embodiment of the present invention.

5        Fig. 2 shows an embodiment of the present invention wherein a positive lens is used as the distal optics.

Fig. 3 shows an embodiment of the present invention wherein a negative lens is used as the distal optics.

10       Fig. 4 shows an embodiment of the present invention wherein a concave "dimple" is formed on the distal end of the HRI tunnel rod.

Fig. 5 shows an embodiment of the present invention wherein an eyepiece is used as a means of viewing the image produced.

15       Fig. 6a and 6b show an embodiment of the present invention wherein the shaft is of an all-glass, integral construction.

20       Fig. 7 shows an embodiment of the present invention wherein the shaft of the device is rectangular in cross-section.

Figure 8 shows an embodiment of the present invention wherein the tunnel rod is surrounded by a solid light-conducting sleeve.

25       Figure 9 shows an embodiment wherein there is provided a twin-channel light shaft which produces a stereo image pair from a single object.

Figure 9a shows a cross-section of the shaft shown in the embodiment of Figure 9.



Figure 10 shows an embodiment wherein there is provided an arrangement of relay optics which produces a stereo image pair from light transferred by a single HRI tunnel rod and single set of distal optics.

5       As shown in Fig. 1, a solid transparent HRI tunnel rod 1 serves as an optical tunnel to allow the image formed by a relatively simple lens 5 at the distal end to be viewed by the eye, via an image-recording device 3, which may be a CCD camera or the like. In a preferred embodiment, the  
10       HRI tunnel rod 1 is made of glass; however, other transparent materials, including conventional polymers such as lucite, or even water, can be used for the rod's composition. The HRI tunnel rod shortens the apparent distance from the proximal to the distal end by virtue of  
15       its refractive index being greater than that of air.

      If the walls of the HRI tunnel rod are modified in order to reduce internal light scattered or reflected from them, the resultant images are vastly improved over images obtained in the absence of such modification. Various  
20       methods may be used to accomplish this. A preferable method is by grinding, etching, sandblasting, or otherwise roughening the surface of the rod and then firing it at an elevated temperature in a reducing atmosphere, such as a hydrogen atmosphere. The hydrogen reduces certain  
25       metallic oxides present in the glass, such as lead or arsenic, to metal and causes the surface of the HRI tunnel rod to create a thoroughly blackened surface 7. The rod may be composed of a conventional high-index, lead-

containing glass in order to aid in the hydrogen-firing process. Such a reducing treatment is disclosed in U.S. Patent No. 5,078,773 to Thomas.

5 Another, less-effective method of modification is to grind, sandblast, or otherwise roughen the wall surface of the HRI tunnel rod and coat the so-treated surface with a black material, such as paint or resin, which preferably has a refractive index which closely matches that of the rod.

10 The distal optics 5, which may be either a positive or a negative lens or lens system, forms an image of the object space, generally a volume of low accessibility, that image being of generally reduced size. The object space may be, for example, the inside of an abdominal cavity.  
15 However, rigid endoscopes are also used for viewing the inside of industrial components such as weldments or castings.

The HRI tunnel rod 1, by virtue of its blackened surface and zero-focussing power, will "transfer" the image  
20 light along the endoscope shaft with minimal stray light interfering with the image. A relay lens 17 is provided at the proximal end of the HRI tunnel rod 1 to focus the image formed by the distal objective lens 5 onto the image-recording device 3. A rigid, elongated tubular housing 37  
25 comprises a sheath made of stainless steel or glass, or other material.

A ring of optical fibers 25 is formed around the tunnel rod 1 to provide illuminating light 2 to illuminate

the field of view 6. These fibers 25 terminate at the distal end of the shaft and have polished ends. The fibers 25 are routed in the handle 27 of the endoscope so as not to interfere with the optical path from the relay lens 17 to the imaging device 3, and are gathered together in a compact, generally circular bundle 29 and bonded into a tubular connector 31 mounted at the side or proximal end of the handle.

Light from a remote light source 33, which may be a Xenon arc lamp or other high intensity lamp, is transmitted to the connector 31 by means of a fiber optic cable 35. This cable may be separable or may be integral with the bundle 29.

A preferred embodiment of the endoscope has a separable shaft and handle to provide 1) disposability of the shaft, 2) interchangeable shafts of varying diameters or lengths, or 3) autoclavability of the shaft portion of the endoscope. In this embodiment, the shaft may consist of a glass HRI tunnel rod and a surrounding ring of light-conducting material, fibers or clad rods. A surrounding housing such as a stainless steel or glass tube may be provided, or the light-conducting material may serve also as a housing. For example, an aluminum-coated plastic tube may serve as both the housing and light-guide illuminator.

A simple mechanical coupling 39, Figure 1, may be used to lock the shaft into the handle. Such coupling may be a ball detent, collet, threaded locking ring, or other means.

The handle may contain the relay lens placed just

behind the proximal end of the HRI tunnel rod 1, and may also contain a fiber bundle resembling a "cobra head" to form a ring of fibers 41 to optically couple to those in the shaft in very near contact (or actual contact) at a coupling point 43. A suitable light-tight ring seal 45 is used to prevent any of the light carried by the fibers 41 from entering the optical path of the image light in the space between the HRI tunnel rod 1 and the relay lens 17.

Whereas the handle 27 may not be steam sterilizable, it may be gas sterilized in ethylene oxide gas or disinfected and/or sterilized by other appropriate means. The housing 37 may be made from metals or plastic or combinations thereof.

As shown in Fig. 2, if a positive objective lens 11 is used as the distal optics, a real image 9 is formed at or near the entrance face of the HRI tunnel rod 1.

As shown in Fig. 3, if a negative objective lens 13 is used, a virtual image 15 is formed in front of the negative lens 13. The distal and proximal optics in each of the embodiments may be simple plano-convex or plano-concave lenses, combinations of simple lenses, or more complex structures with aspheric surfaces for correction of image aberrations.

As shown in Figure 4, a simple form of objective lens may be utilized by incorporating a concave "dimple" 19 into the distal end of the HRI tunnel rod 1. The dimple 19 may be formed by grinding and polishing a concave surface directly into the end of the solid glass HRI tunnel rod 1,

or such may be accomplished by hot-pressing the end of the rod.

As shown in Figure 5, the real image produced by relay lens 17 can be viewed directly through an eyepiece 21. In this case, if a negative objective lens is used, a means for erecting the image is required. An aperture 23 placed between the relay lens 17 and the HRI tunnel rod 1 can be used to cut off rays which travel very close to the inner-diameter of the blackened surface 7 of HRI tunnel rod 1 and which may be distorted due to any slight inhomogeneities in the rod near these walls.

The entire shaft, including the HRI tunnel rod 1 and fibers 25, may be made of low cost materials, and hence be disposable after one use or after limited use. In one such embodiment, shown in Figure 6a and 6b, the shaft is made of an all-glass construction with a pre-blackened HRI tunnel rod 1 surrounded by glass-clad fibers 51a or keystone-shaped rods 51b, and surrounded by a glass housing 53 having a low coefficient of thermal expansion. This provides a mechanically very rugged construction for the shaft. Although both glass-clad fibers 51a and keystone-shaped rods 51b appear in FIG. 6a for purposes of illustration, an embodiment using a single light-conducting material may be preferable for purposes of design-simplification.

The outer glass housing 53 may also be blackened, such as by firing in hydrogen, to produce a glossy black finish. Such an integral shaft may be made by assembling the pre-

drawn and blackened glass rod along with a ring of light pipes into the glass housing and redrawing at a relatively low drawing ratio (such as 2:1) to thermally fuse all the glass elements into a sealed, void-free rod.

5           To reduce internal reflection or scattering of light in this version, the surface of the HRI tunnel rod, which is oversized in diameter prior to the final draw to the desired diameter, may be modified by very coarse grinding and/or cutting of shallow, circular, or spiral  
10           grooves (by sandblasting through a mask, for example) so as to produce shallow baffles inside the HRI tunnel rod. The rod may then be fired in a reducing atmosphere to blacken the roughened and grooved exterior surface. This also causes the interior "surface" of the rod to appear very  
15           black.

          When this rod is assembled with the light piping clad rods in a glass tube and redrawn, there will be some smoothing and flattening of the rough surface and the grooves, but the remaining roughness and modified grooved  
20           surface will still adequately serve to suppress the internal reflection and scattering of the HRI tunnel rod after final drawing.

          In the embodiments shown in Figs. 1-6, the housing and HRI tunnel rod are formed so as to be circular in cross-  
25           section. However, as shown in Fig. 7, it is also foreseeable that an HRI tunnel rod 1a which is rectangular in cross-section could be used. Such an embodiment might be advantageous in order to conform the shape of the image

output to the shape of the detector used. For example, CCD detectors are generally available in rectangular form, and thus an endoscope which uses such a detector would benefit from a rod and housing which produce a rectangular image.

5           Figure 8 illustrates an embodiment wherein a light-conducting sleeve 67 provides a cavity for transfer of illumination energy to the object. A typical illumination input point is shown at 78. Use of a plastic light-conducting sleeve is compatible with the concept of  
10 ultrasonically or chemically welding plastic distal optics 68 into the distal tip. The shaft depicted in Figure 8 is completed by inserting the HRI tunnel rod 1 via the opening at the proximal end 69. Flexible tabs 70 at the proximal end of the light-conducting sleeve could be used to retain  
15 the HRI tunnel rod. Examples of distal end configurations 71 and 72, providing different illumination fields, are also shown.

          Figures 9 and 10 show configurations which generate "stereo images", such images being the source of parallax  
20 data which reveals the object distance from the distal tip. In Figure 9, the "stereo images" are generated by duplicating the basic optical system of Figure 1 within a single shaft. This embodiment comprises dual distal optics 5a and dual proximal optics 17a, and dual HRI tunnel rods  
25 1b and 1c. In Figure 10, the shaft contains one set of distal optics 5b and one HRI tunnel rod 1. Two sets of relay optics 61, 62 interact with and are coupled to the shaft optics via beam splitter 60 to form images 63 and 64.

With properly-designed relay optics, the stereo base 65 in the embodiment of Figure 10 can approach or even exceed the HRI tunnel rod's diameter. The ability to increase the stereo base beyond the HRI tunnel rod's diameter provides an increased depth resolution.

The above embodiments are preferred for producing endoscopes which utilize an HRI rod having an aspect ratio of about 45:1 and an area of illuminating fibers approximately equal to the cross-sectional area of the rod. However, in certain circumstances where operating conditions are extreme, i.e., where a very wide field of view (90 degrees, for example) is required, and/or where a large object distance (over 100 millimeters, for example) and a high aspect ratio rod are required, the level of illumination at the CCD may be insufficient to reproduce satisfactory video images at the monitor. Since the rod aspect ratio is dictated by the endoscopic requirements, such as those for performing laparoscopy, the overall cross-section of the endoscope is similarly limited (typically 9-11 millimeters diameter); and, the light source (typically a Xenon arc lamp) cannot readily be made more intense. Thus, the preferred means for increasing the illumination on the CCD is to increase the refractive index of the HRI rod 1 (FIG. 1) to the highest practical level, e.g., up to 1.95.

A refractive index increase of the HRI rod shifts the apparent position of the distal lens 5 (FIG. 1) toward the proximal relay lens 17 (FIG. 1), thus shortening the



optical distance between the distal "window" (actually the distal lens) and relay lens 17. With a decreased optical distance between the "window" and relay lens 17, a shorter relay focal length is required to fill the CCD ship with an image of the "window." Illumination E at the CCD chip is proportional to the squared reciprocal of the relay f-number:

$$E \propto \left(\frac{D}{f}\right)^2$$

where f is the relay focal length and D is the HRI rod diameter.

Other methods of increasing illumination at the CCD include 1) decreasing the field of view by means of longer focal length distal optics, and 2) decreasing the image size at the CCD by means of shorter focal length relay optics. Both of these methods may produce images which are less acceptable in some marketplaces.

If further illumination is required, additional optical means can be used. Figs. 11 and 12 illustrate "hybrid" embodiments wherein such additional optical means are used.

Referring to FIG. 11, a tunnel rod having blackened walls is modified by "breaking" it into two (or more) segments 121, 123 and adding a relaying lens or lenses in the spaces between the rods. As shown in Fig. 11, the relay lens comprises modified ends 125, 127 of the tunnel rods 121, 123. Modification is performed, e.g., by contouring a convex surface onto an end portion of at least

one of the tunnel rods such that it forms an image 131 of the object 132 inside or near the end of the proximal rod, the image 131 preferably being of less than or equal diameter to the rod. This internal (relayed) image 131 is, in turn, focused onto a CCD by a proximal relay lens 135. The image 131 and distal "window" image 137 are both now much nearer the proximal relay lens 135, which requires a correspondingly shorter focal length. The focal length of proximal relay lens 135 decreases to at least half of its original value and increases the illumination on the CCD 133 by the inverse square of this ratio.

Certain variations on the hybrid embodiment may be made without departing from the spirit and scope of the invention. Examples of such variations include, e.g., using a more complex objective lens 138, such as one or more negative, positive, or combinations of lenses, aspherizing both tunnel rods to relay the image, adding one or more lenses between the tunnel rods to improve the quality of the relayed images, 131, 137 (i.e., so as to correct spherical and chromatic aberration).

The embodiment shown in Fig. 11 is potentially the least costly version of the hybrid embodiments, and therefore may provide economically-practical disposability of the separable shaft.

Fig. 12 shows a "hybrid" tunnel scope with an intermediate relay lens to extend the length, e.g., from 8 inches to 16 inches. This embodiment preferably uses a 6-millimeter diameter rod 101 which is 200 millimeters long

with a concave tip (objective lens) 109. A second 8-millimeter diameter rod 103 which is 200 millimeters long with plano ends is further provided. A pair of 115-millimeter EFL achromatic doublets 105, 107 are placed  
5 face-to-face between the rods 101, 103. A 50-millimeter relay lens 111 and a 5X eye piece 113 are utilized. The 5X eyepiece is preferably made up of two achromatic lenses each having an focal length of about 80mm. The exit pupil is preferably approximately 1.5 millimeters in diameter  
10 with an apparent field of about 20 degrees. The apparent field can be varied by adjusting the position of the final relay lens 111.

For right-angle viewing, the above embodiment could be supplemented with a slip-on mirror tube.

15 While the invention has been particularly described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

20

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An endoscope device useful for remotely examining  
5 a cavity, comprising:

distal optics for forming an image of an object area  
to be examined;

a tunnel rod of transparent material having an index  
of refraction greater than 1 for conducting image light  
10 from a distal end to a proximal end of said endoscope, said  
tunnel rod having an outer surface which is blackened  
effectively to inhibit internal scattering of light;

proximal optics located at a proximal end of said  
tunnel rod, said proximal optics serving to relay an image  
15 of an object area to be examined; and,

a means for receiving and displaying said image  
relayed from said proximal objective lens.

2. The device according to claim 1, further  
20 comprising:

second distal optics for forming a second image  
of an object area to be examined;

a second tunnel rod of transparent material  
having an index of refraction greater than 1 for conducting  
25 second image light from said distal end to said proximal  
end of said endoscope, said second tunnel rod having a  
second outer surface which is blackened effectively to  
inhibit internal scattering of light;

second proximal optics located at said proximal end of said tunnel rod, said second proximal optics serving to relay a second image of said object area to be examined;

5           3. The device according to claim 2, wherein said means for receiving and displaying said image relayed from said proximal optics further comprises means for receiving and displaying said second image of said object area to be examined.

10

4. The device according to claim 1, wherein said proximal optics comprises means for processing a plurality of images containing parallax.

15           5. The device according to claim 4, wherein said means for processing a plurality of images comprises a beam splitter and first and second proximal lens means.

20           6. The device according to claim 3, wherein said means for receiving and displaying said image relayed from said proximal optics comprises a plurality of CCD detectors.

25           7. The device according to claim 3, wherein said means for receiving and displaying said image relayed from said proximal optics comprises a plurality of eyepieces.

8. The device according to claim 1, wherein said

transparent material having an index of refraction greater than 1 is glass.

9. The device according to claim 1, further  
5 comprising a tubular housing encasing said tunnel rod.

10. The device according to claim 9, wherein said  
tubular housing comprises a ring of light-conducting  
members surrounding said tunnel rod and extending from a  
10 proximal end of said tunnel rod to a distal end of said  
tunnel rod for delivering illumination to said object area.

11. The device according to claim 10, wherein said  
light-conducting members comprise optical fibers.

15

12. The device according to claim 9, wherein said  
tubular housing comprises a light-conducting sleeve which  
provides a cavity for transfer of illumination energy to  
said object area to be examined.

20

13. The device according to claim 10, wherein said  
light-conducting members and said tunnel rod are comprised  
of a glass construction, and wherein said light conducting  
members and said tunnel rod are fused together to form an  
25 integrated glass shaft.

14. The device according to claim 9, wherein said  
light-conducting sleeve is of a plastic construction, and

wherein said tunnel rod and said light-conducting sleeve are assembled together to form an integrated glass/plastic shaft.

5           15. The device according to claim 10, wherein said light-conducting members comprise keystone-shaped rods.

10           16. The device according to claim 1, wherein said transparent material having an index of refraction greater than 1 is of a plastic-construction.

          17. The device according to claim 1, wherein said tunnel rod is circular or rectangular in cross-section.

15           18. The device according to Claim 1, wherein said distal optics comprises at least one lens, and wherein said at least one lens has negative power.

20           19. The device according to Claim 1, wherein said distal optics comprises at least one lens, and wherein said at least one lens has positive power.

25           20. The device according to Claim 1, wherein said means for receiving and displaying said image relayed from said proximal optics comprises a CCD camera or an eyepiece for direct viewing of said image.

          21. The device according to Claim 1, wherein said

distal optics comprises at least one aspheric surface for correction of aberration in said image.

22. The device according to Claim 1, wherein said  
5 distal optics comprises a ground and polished end portion of said tunnel rod.

23. The device according to Claim 1, wherein an  
10 aperture stop is placed over said proximal end of said tunnel rod for occluding light entering said proximal optics from said tunnel rod.

24. The device according to Claim 1, wherein a light-tight seal is provided at said proximal end of said tunnel  
15 rod to prevent light from entering the tunnel rod at or near said proximal end of said tunnel rod.

25. The device according to Claim 9, wherein a handle  
20 is provided at said proximal end and is connectable to said tubular housing.

26. The device according to Claim 25, further  
comprising means for removably connecting said tubular  
housing and said tunnel rod to said handle so as to make  
25 said tubular housing and said tunnel rod removable as an integral component for replacement, sterilization, or other servicing.



27. The endoscope according to claim 1, wherein said tunnel rod comprises a component which is integral with a plurality of light-conducting members and which is detachable for replacement, sterilization, or other servicing.

28. A method of producing an endoscope shaft which is capable of accurately transmitting image light from a distal end of the endoscope to a proximal end thereof, comprising:

modifying a rod of transparent material by blackening the outer surface of said rod, thereby creating an inner surface which minimizes the amount of light scattered and reflected within said rod to an extent that veiling glare and contrast reduction of an image transmitted by said rod are reduced; and,

surrounding said rod with a ring of light-conducting members, said light-conducting members being oriented so as to run generally parallel to said rod.

29. The method according to claim 28, further comprising:

fusing said rod and said light-conducting members so as to form a single, integral shaft component.

30. The method according to claim 28, wherein said modifying step includes a step of firing said rod in a reducing atmosphere.

31. The method according to claim 30, wherein said reducing atmosphere is hydrogen.

5           32. An endoscope device useful for remotely examining a cavity, comprising:

distal optics for forming an image of an object area to be examined;

10           a first tunnel rod of transparent material having an index of refraction greater than 1 for conducting image light from a distal end of said first tunnel rod to a proximal end of said first tunnel rod, said first tunnel rod having an outer surface which is blackened effectively to inhibit internal scattering of light;

15           a second tunnel rod of transparent material for conducting image light from a distal end of said second tunnel rod to a proximal end of said second tunnel rod, said second tunnel rod having an outer surface which is blackened effectively to inhibit internal scattering of light;

20

proximal optics located at a proximal end of said second tunnel rod, said proximal optics serving to relay an image of an object area to be examined to an image receiving and displaying means; and,

25           a relay lens between said first and second tunnel rods for relaying an image from said distal optics to said proximal optics.

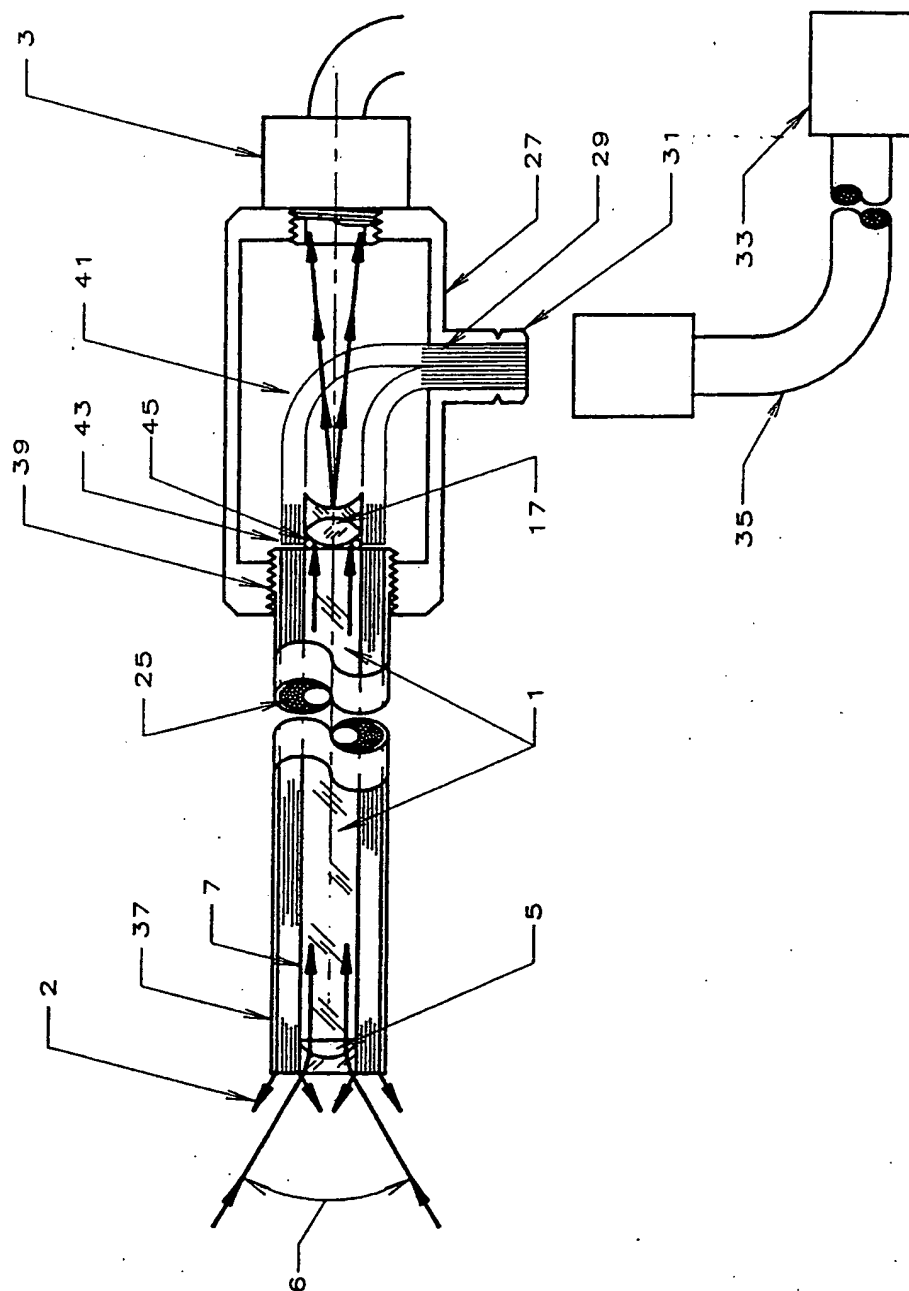


FIGURE 1

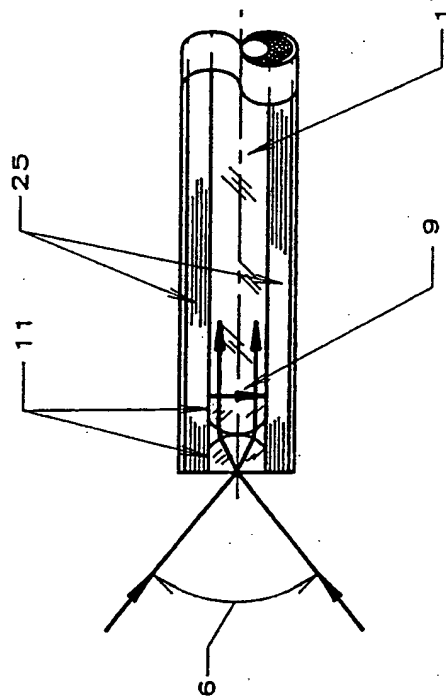


FIGURE 2

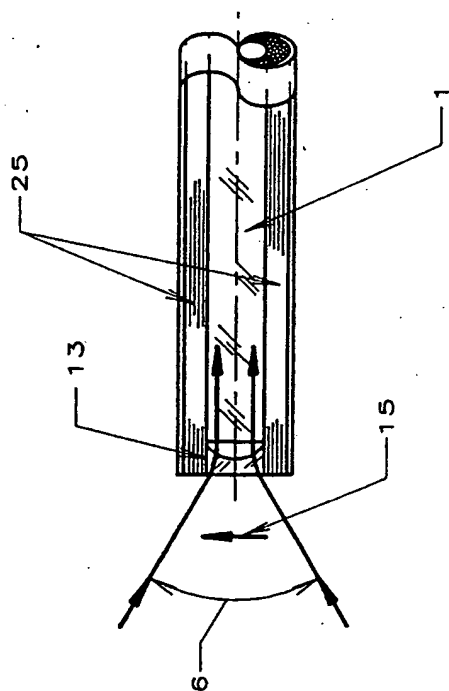


FIGURE 3

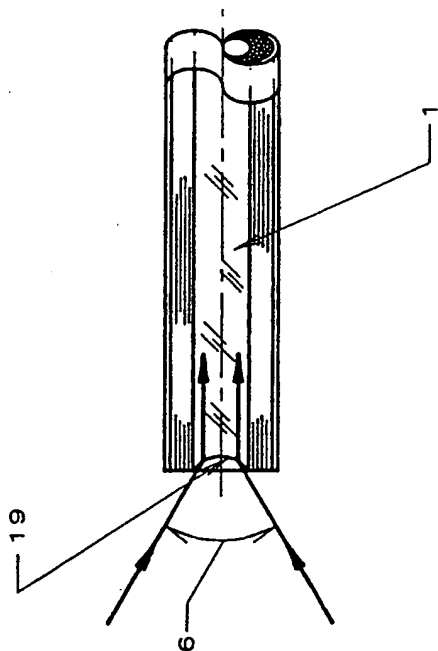


FIGURE 4

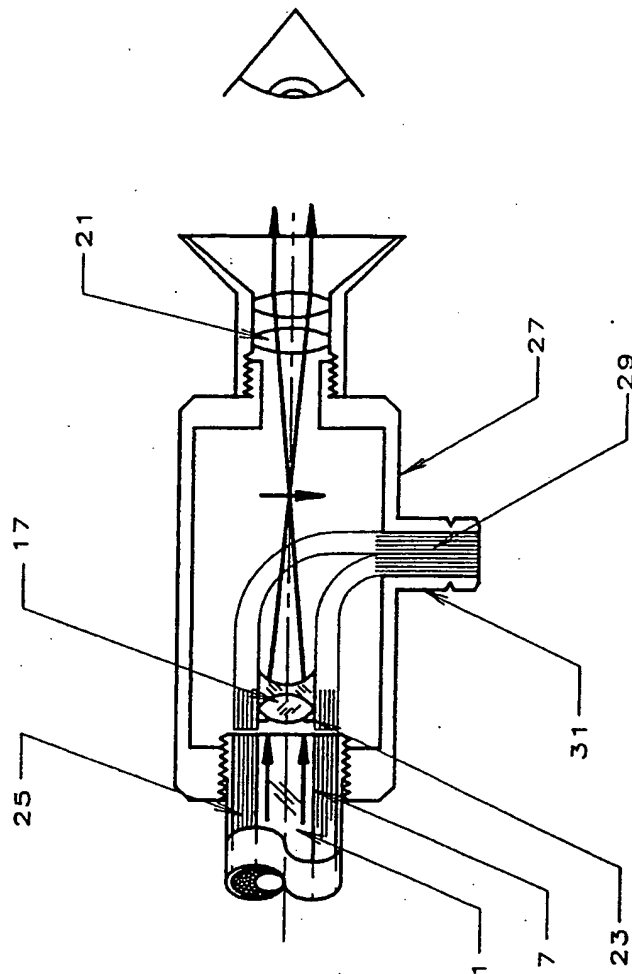


FIGURE 5

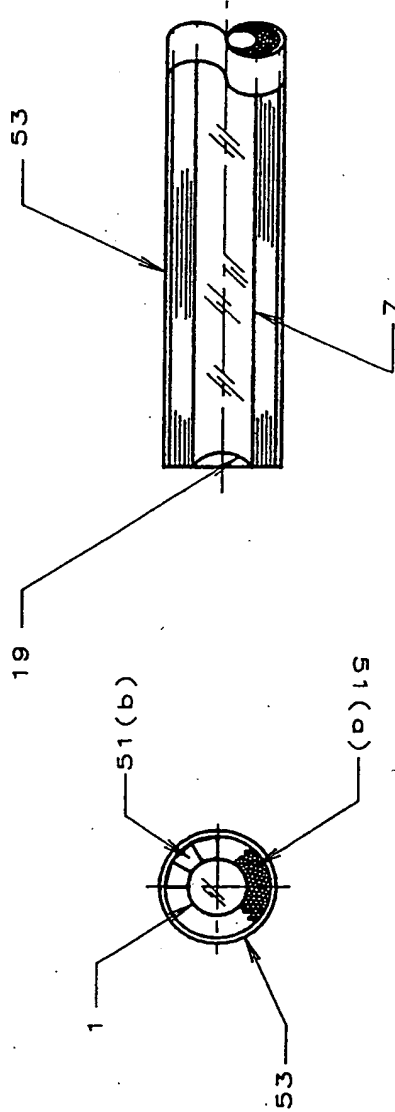


FIG. 6(b)

FIG. 6(a)



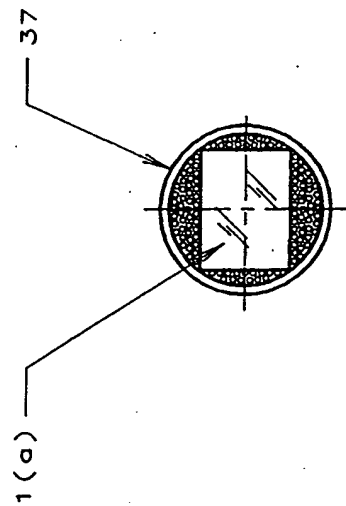
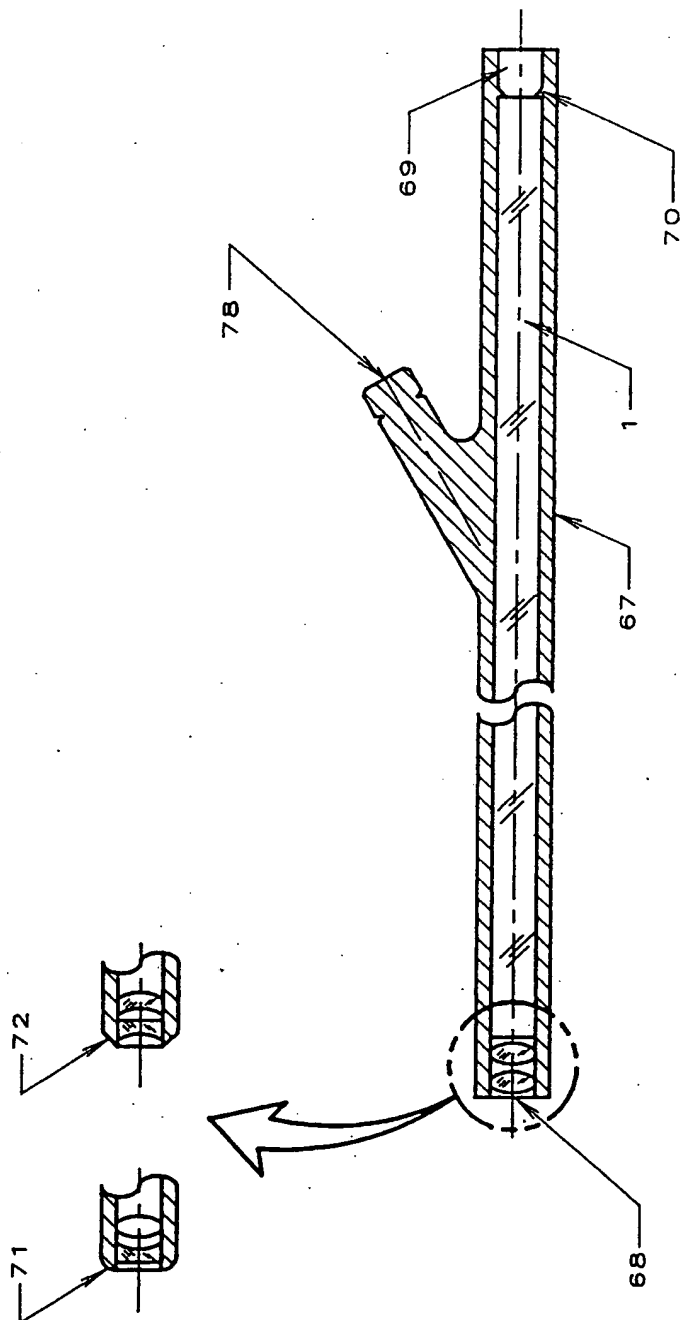


FIGURE 7



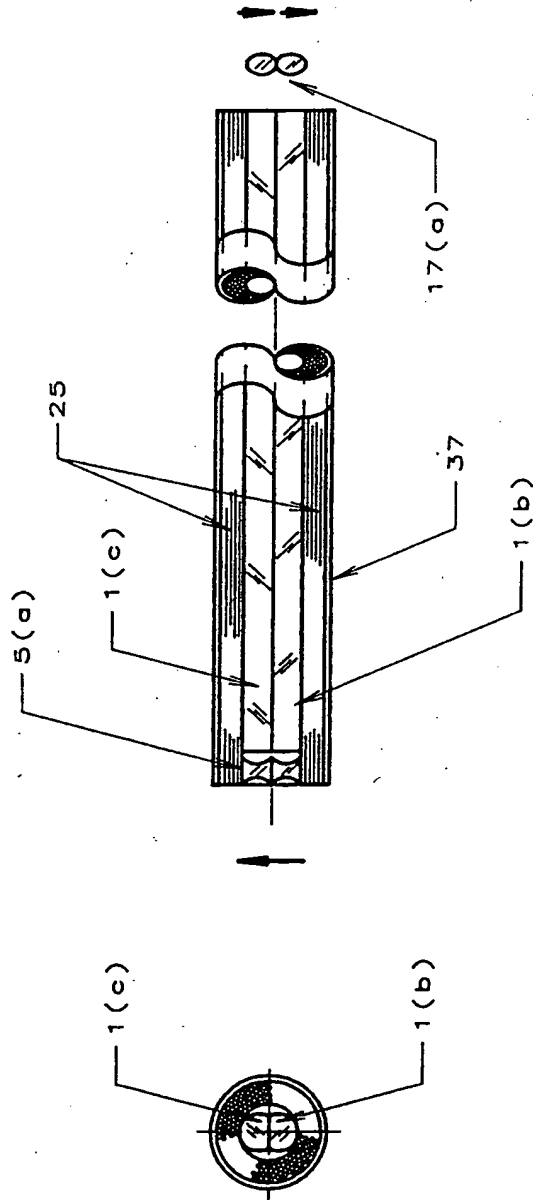


FIG. 9(a)

FIGURE 9

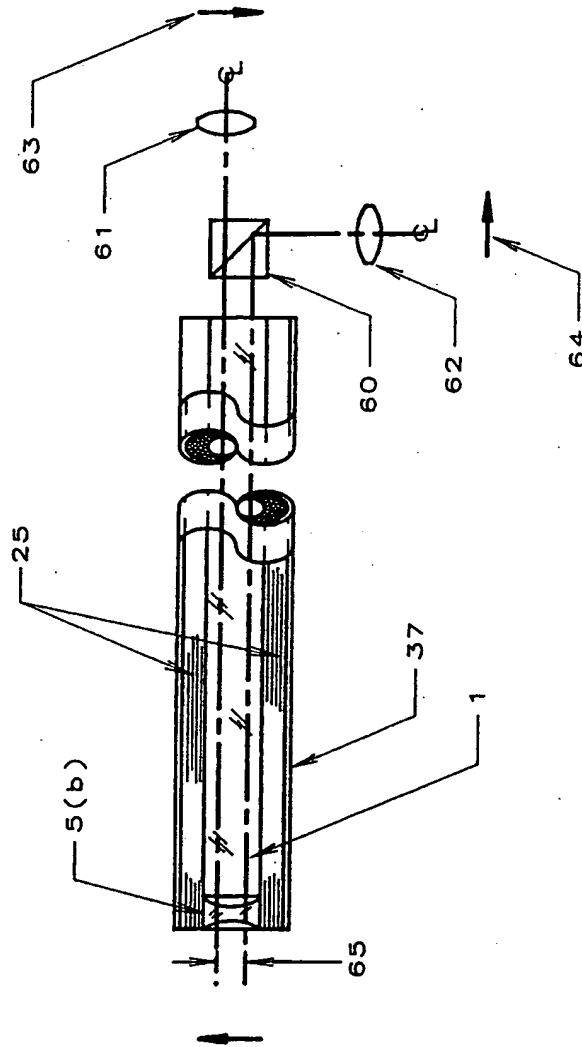


FIGURE 10

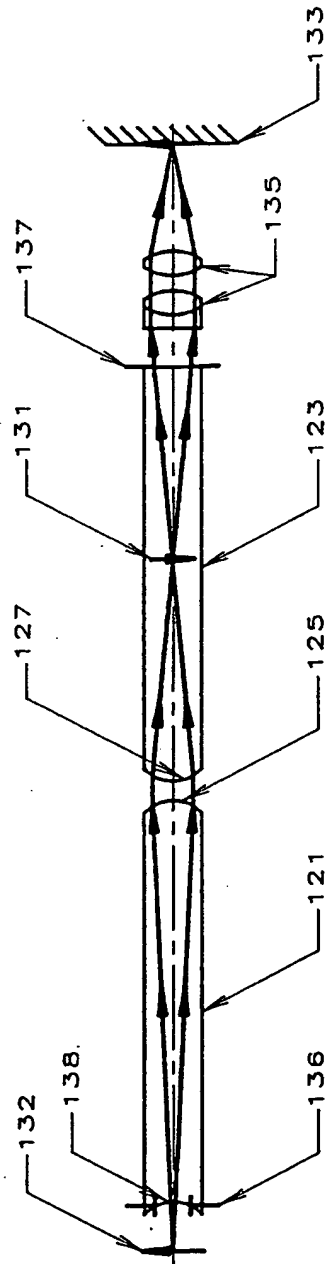


FIGURE 11

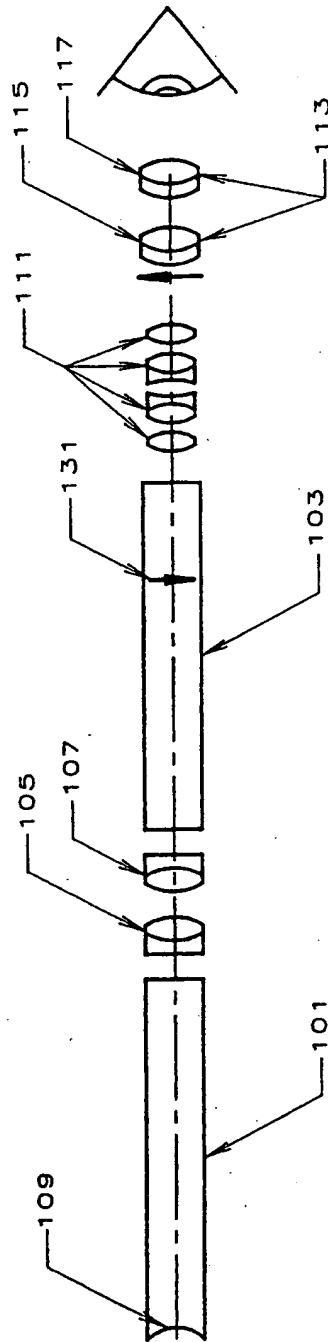


FIGURE 12

# INTERNATIONAL SEARCH REPORT

International Application No  
**PCT/US 93/12489**

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC 5    A61B1/00    A61B1/04		
According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) IPC 5    A61B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used)		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 100 517 (SUMITOMO ELECTRIC INDUSTRIES, LTD.) 15 February 1984 see page 15, line 2 - page 16, line 14 see page 26, line 6 - page 27, line 22 see page 32, line 6 - line 13 ---	1,8-14, 16,28,29
A	DE,A,38 18 104 (OLYMPUS OPTICAL CO., LTD.) 8 December 1988 see column 26, line 2 - line 31 ---	1-7,11, 12
A	US,A,4 651 201 (A. SCHOOLMAN) 17 March 1987	1-4, 6-12,17
A	see column 4, line 17 - column 6, line 49 --- -/--	20, 26-28,32
<div style="display: flex; justify-content: space-between;"> <span><input checked="" type="checkbox"/> Further documents are listed in the continuation of box C.</span> <span><input checked="" type="checkbox"/> Patent family members are listed in annex.</span> </div>		
<div style="display: flex;"> <div style="flex: 1;"> <p>* Special categories of cited documents :</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="flex: 1;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p> </div> </div>		
Date of the actual completion of the international search  <div style="text-align: center; font-weight: bold;">9 May 1994</div>		Date of mailing of the international search report  <div style="text-align: center; font-weight: bold;">10. 06. 94</div>
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+ 31-70) 340-3016		Authorized officer  <div style="text-align: center; font-weight: bold;">Rieb, K.D.</div>

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 93/12489

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO,A,90 14040 (MEDICAL DIMENSIONS, INC.) 29 November 1990	1-5, 8-11,17
A	see page 4, line 32 - page 8, line 38 ---	20,22, 28,32
A	EP,A,0 019 792 (CARL ZEISS) 10 December 1980 see page 5, line 6 - page 7, line 4 ---	1,3-7, 19,20
A	US,A,5 078 773 (N.I. THOMAS) 7 January 1992 cited in the application see column 3, line 47 - column 4, line 49 -----	28-31



# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 93/12489

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-0100517	15-02-84	JP-A-	59154420	03-09-84
		JP-A-	59155824	05-09-84
		JP-A-	59164516	17-09-84
		JP-A-	59182407	17-10-84
		JP-A-	59195215	06-11-84
		JP-A-	59024805	08-02-84
		AU-B-	557043	04-12-86
		AU-A-	1742583	02-02-84
		US-A-	4784144	15-11-88
-----				
DE-A-3818104	08-12-88	JP-A-	63294509	01-12-88
		US-A-	4862873	05-09-89
-----				
US-A-4651201	17-03-87	US-A-	4559555	17-12-85
		US-A-	5281957	25-01-94
		US-A-	4706117	10-11-87
-----				
WO-A-9014040	29-11-90	US-A-	4924853	15-05-90
		AU-A-	5562990	18-12-90
-----				
EP-A-0019792	10-12-80	DE-A-	2919678	20-11-80
		JP-A-	55155642	04-12-80
		US-A-	4364629	21-12-82
-----				
US-A-5078773	07-01-92	US-A-	4989960	05-02-91
-----				

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**